Numerical Studies Of Rough Surface Scattering Models

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LONG-TERM GOAL

My long-term goal is to be able to predict the effects of a rough air-sea interface and a rough sea-bottom interface on acoustic propagation. These are of particular importance for multiple surface interactions which can occur in shallow water environments.

OBJECTIVES

I have continued to work on the development of theoretical surface scattering models. My objective is to discover or devise a model that accurately predicts scattering from rough surfaces but which also can be used in practical models of acoustic propagation and scattering. In conjunction with this objective, I have been working with another ONR researcher to develop an exact numerical method for testing the accuracy of theoretical models.

APPROACH

For the development of the theoretical surface scattering models, I have been performing numerical studies of both the small slope approximation and the non-local small slope approximation. This has involved examining the theory, deriving equations for both the coherent reflection loss and the incoherent scattering cross section, and then generating programs to calculate these quantities for different surface spectra. Results have been obtained for different surface statistics and angles of incidence. These results have been compared with "exact" numerical results to ascertain their accuracy. Much of this work has been done in collaboration with Eric Thorsos. I have also been working with John Schneider in his development of the finite-difference time-domain (FDTD) method for rough surface scattering. As with integral equation approaches, no approximations are made to the underlying equations, and the method is exact in this sense. We are implementing FDTD algorithms to obtain ``exact" numerical results for different types of rough interfaces.

WORK COMPLETED

The coherent reflection loss equation for the non-local small slope approximation (NLSSA) was derived. After some analysis, this equation was approximated, and a computer program was written to calculate the reflection loss for a Pierson-Moskowitz spectrum using the approximate form. Derivation of an approximate form for the NLSSA bistatic scattering cross section was completed, and the third-

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order term of the small slope approximation (SSA) scattering cross section was derived for a Pierson-Moskowitz spectrum. Finally, the FDTD algorithm was implemented for a water-sediment interface. The reflection loss results were reported at several conferences, and a paper on these results has been accepted for publication. The FDTD work has been presented at a conference, and a journal paper is in preparation

RESULTS

A comparison of the coherent reflection loss results obtained using the approximate form of the NLSSA equation with exact integral equation results showed that the approximate form of the reflection loss gives surprisingly accurate results. These results seem to degrade a little as grazing angles get smaller; this is in accordance with the nature of the approximation. However, results are still quite good for a grazing angle of 10°.

The FDTD results for a water-sediment interface were compared with results obtained by Eric Thoros using an integral equation approach. The same sets of surface realizations were used for both methods, allowing an accurate comparison of the two. We found that for both a Gaussian spectrum and a modified power law spectrum, the FDTD and IE results were in excellent agreement. This indicates that the unavoidable numerical error inherent in implementation of a numerical method is negligible for both techniques. From the standpoint of implementation of the FDTD method for more complex geometries (for example, multiple layers and inhomogeneities), this agreement is important to establish since it would be difficult, if not impossible, to compare the FDTD results with those of any other exact approach for complex geometries.

IMPACT/APPLICATIONS

The development of approximate models that accurately predict wave scattering from rough surfaces is important in a number of Navy applications. For example, rough surface scattering models are needed in the simulations used by torpedo guidance and control personnel to test torpedoes. Another application for which rough surface scattering is critical is the detection of underwater mines, especially those buried in soft sediments. Other applications include ship wake detection, communications, and anti-submarine warfare. Of particular importance is that the models be as simple as possible while retaining the physical information necessary for the application.

TRANSITIONS

A number of people have begun to use the results of our studies of the small slope approximation for rough surface scattering. In particular, they are incorporating the lowest-order term of the bistatic scattering cross section into their own models, many of which are for practical applications. Among these people are Darrell Jackson, Anatoly Ivakin, and Peter Dahl.

RELATED PROJECTS

This research is related to projects in (1) propagation in a shallow-water waveguide such as the work of David Berman (University of Iowa) and the work of John Schneider (Washington State University), (2) modeling high-frequency bottom scattering, such as the work of Darrell Jackson (University of Washington Applied Physics Lab), which is the main focus of the ONR high-frequency DRI, (3) long-

range propagation, and (4) rough surface scattering such as the work of Eric Thorsos (University of Washington Applied Physics Lab).

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